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G4H
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(54) Solid state color display system and light emitting diode pixels therefor

(57) A solid state color display system comprises a display matrix (154) consisting of sets of light emitting diodes. Each set comprises groups of red, green and blue light emitting diodes which groups can be variably illuminated by means of driver circuits (173,174,175) using pulse width modulation of an electrical source (176) to display an overall composite color. The pulse width modulation is conducted in response to signals received from picture processing means, such as a video camera (162), off-air receiver (168) or video digitizer (158). The outputs of the driver circuits (173,174,175) are fed to each of a series of eight-row panels (156) of diode sets in the matrix display (154) for illumination thereof. The invention is utilised in a large scale colour display system.

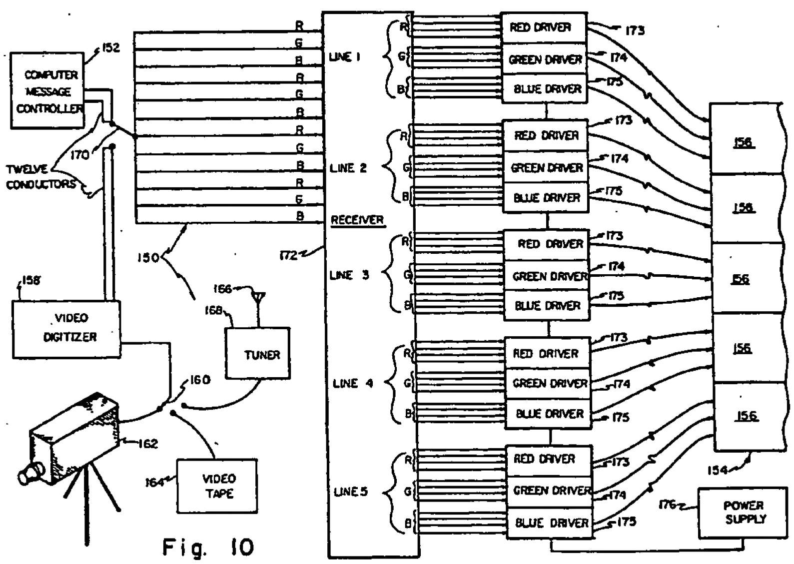

Fig. 10

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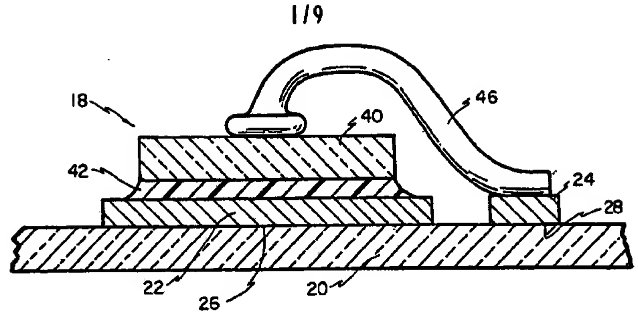

Fig. 1

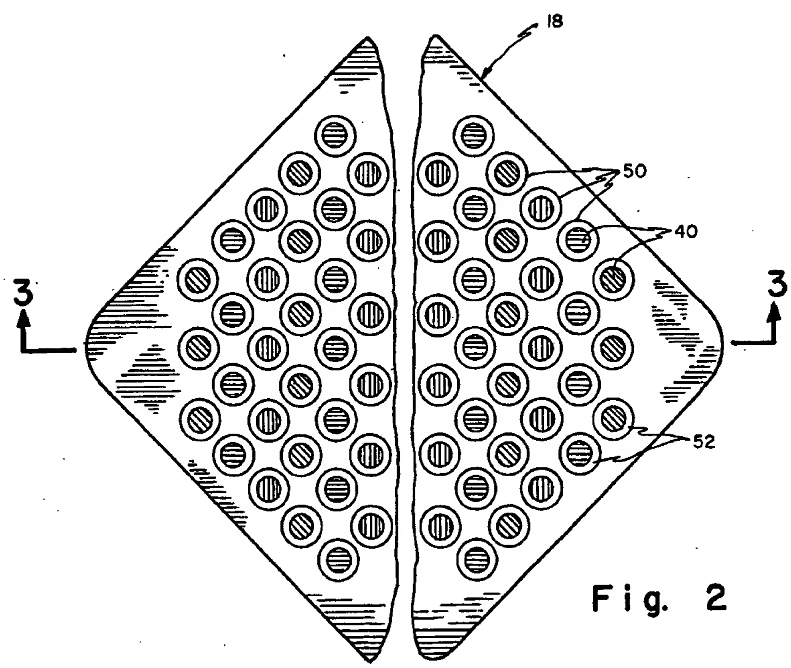

Fig. 2

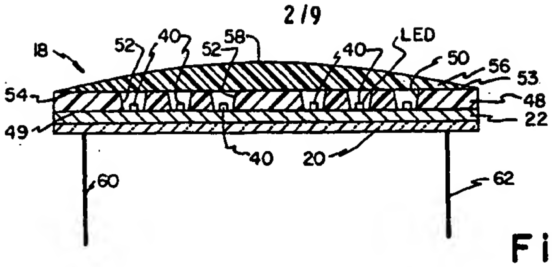

Fig. 3

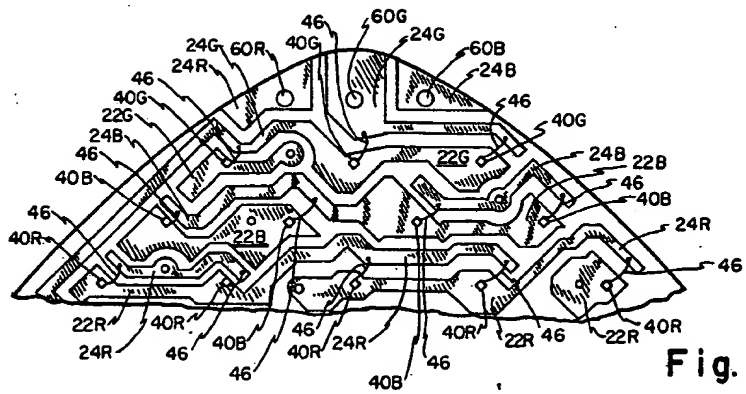

Fig. 4

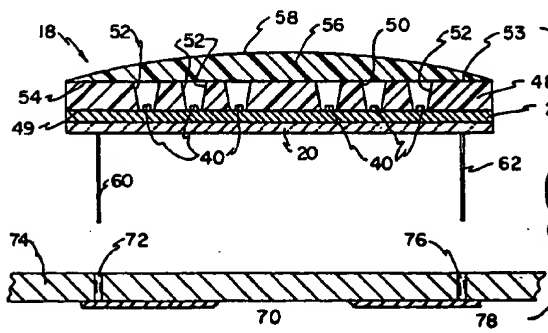

Fig. 6

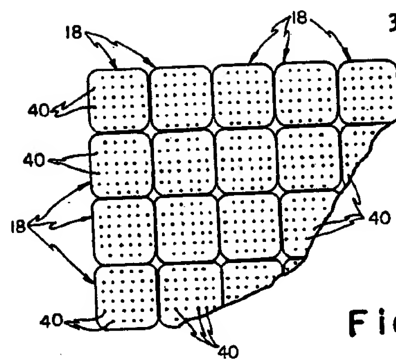
18
18
40
40
18
40
40
40

Fig. 7

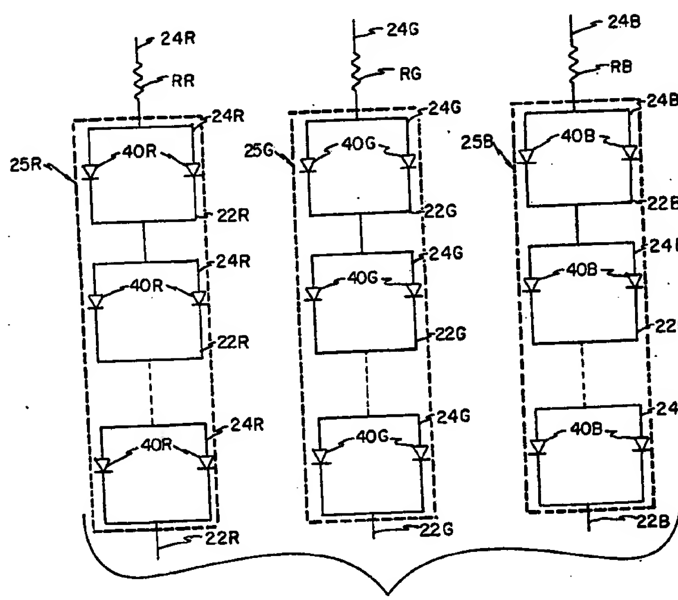
24R
RR
24R
40R
25R
22R
24R
40R
22R
24R
40R
22R
24G
RG
24G
40G
25G
22G
24G
40G
22G
24G
40G
22G
24B
RB
24B
40B
25B
22B
24B
40B
22B
24B
40B
22B

Fig. 5

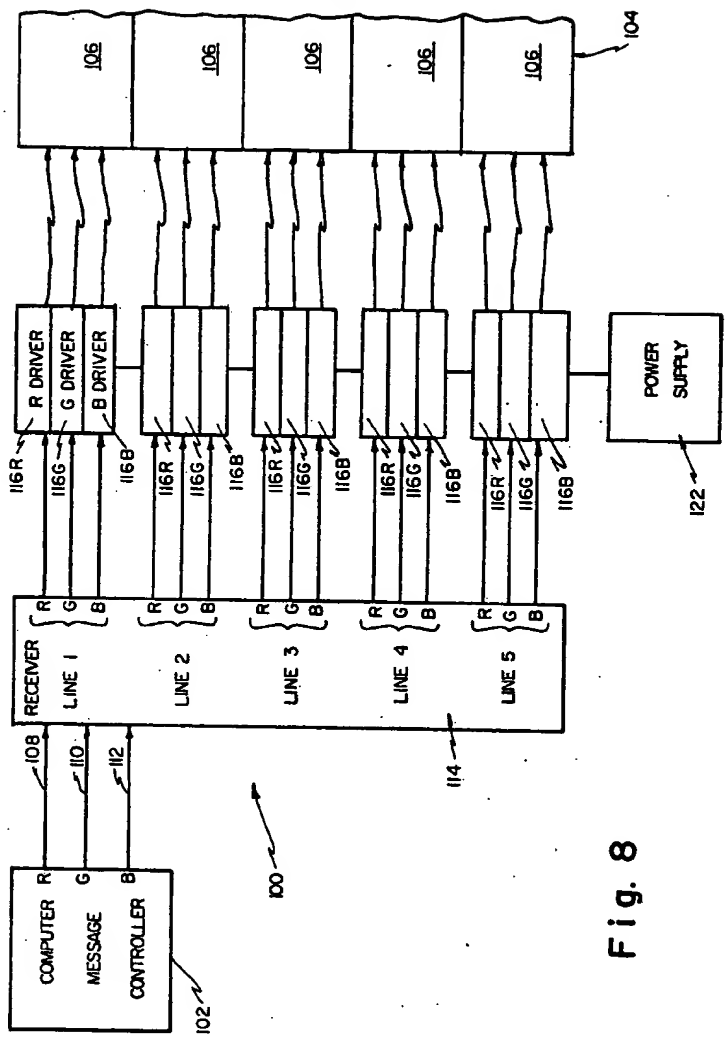
COMPUTER
MESSAGE
CONTROLLER
R
G
B
102
108
110
112
100
RECEIVER
LINE 1
LINE 2
LINE 3
LINE 4
LINE 5
114
116R
116G
116B
R DRIVER
G DRIVER
B DRIVER
POWER SUPPLY
122
106
104

Fig. 8

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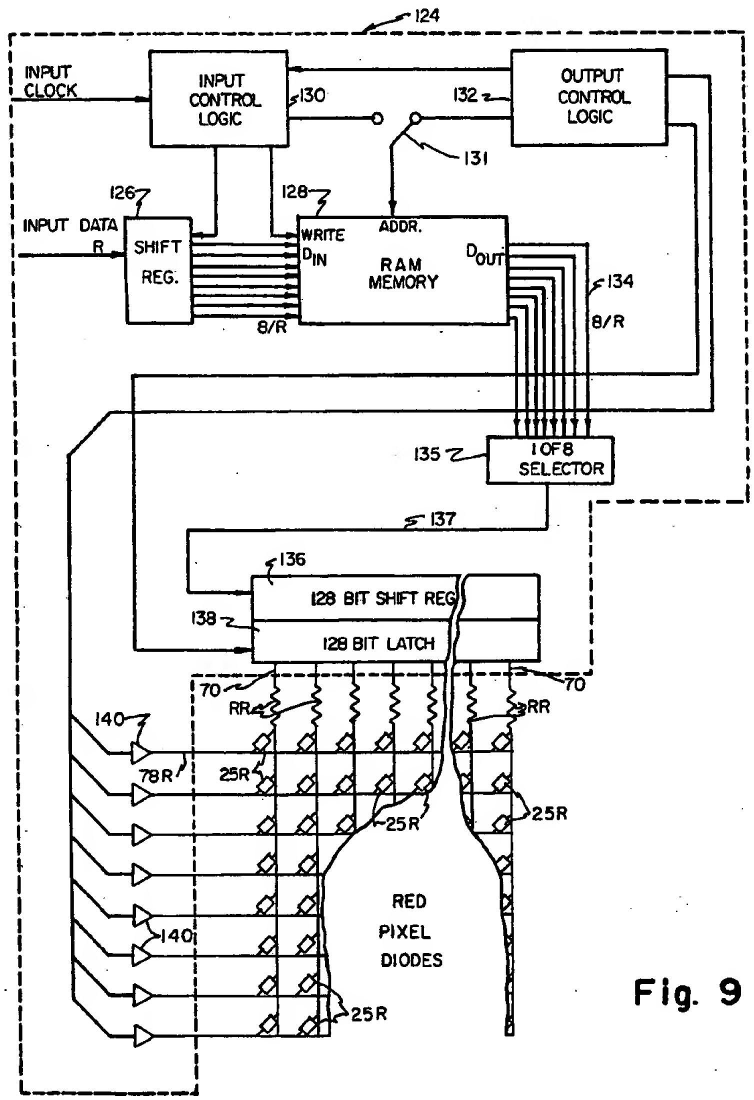

Fig. 9

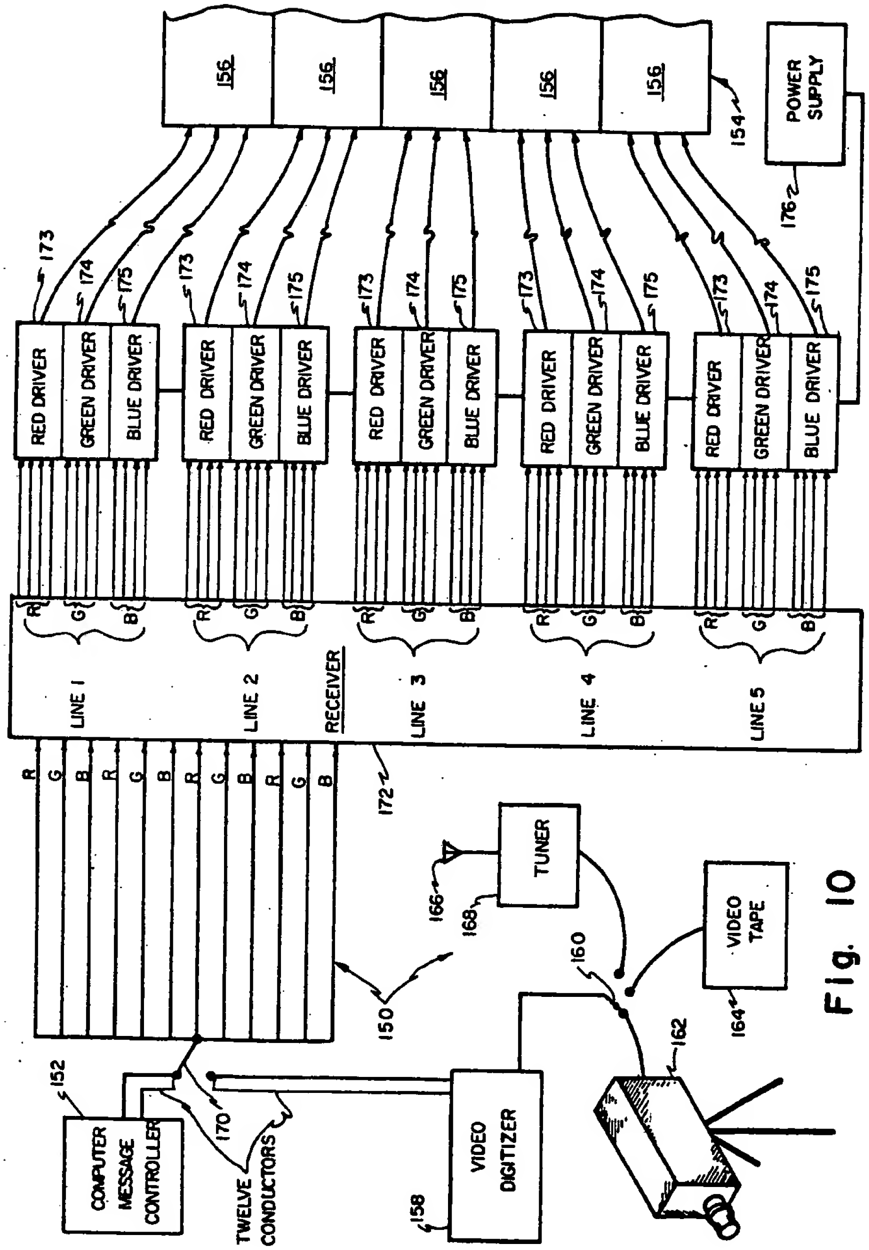
156
156
156
156
156
154
POWER SUPPLY
176
173
174
175
RED DRIVER
GREEN DRIVER
BLUE DRIVER
R
G
B
LINE 1
LINE 2
RECEIVER
LINE 3
LINE 4
LINE 5
172
R G B R G B R G B R G B
150
TUNER
166
168
160
VIDEO TAPE
164
162
VIDEO DIGITIZER
158
COMPUTER MESSAGE CONTROLLER
152
170
TWELVE CONDUCTORS

Fig. 10

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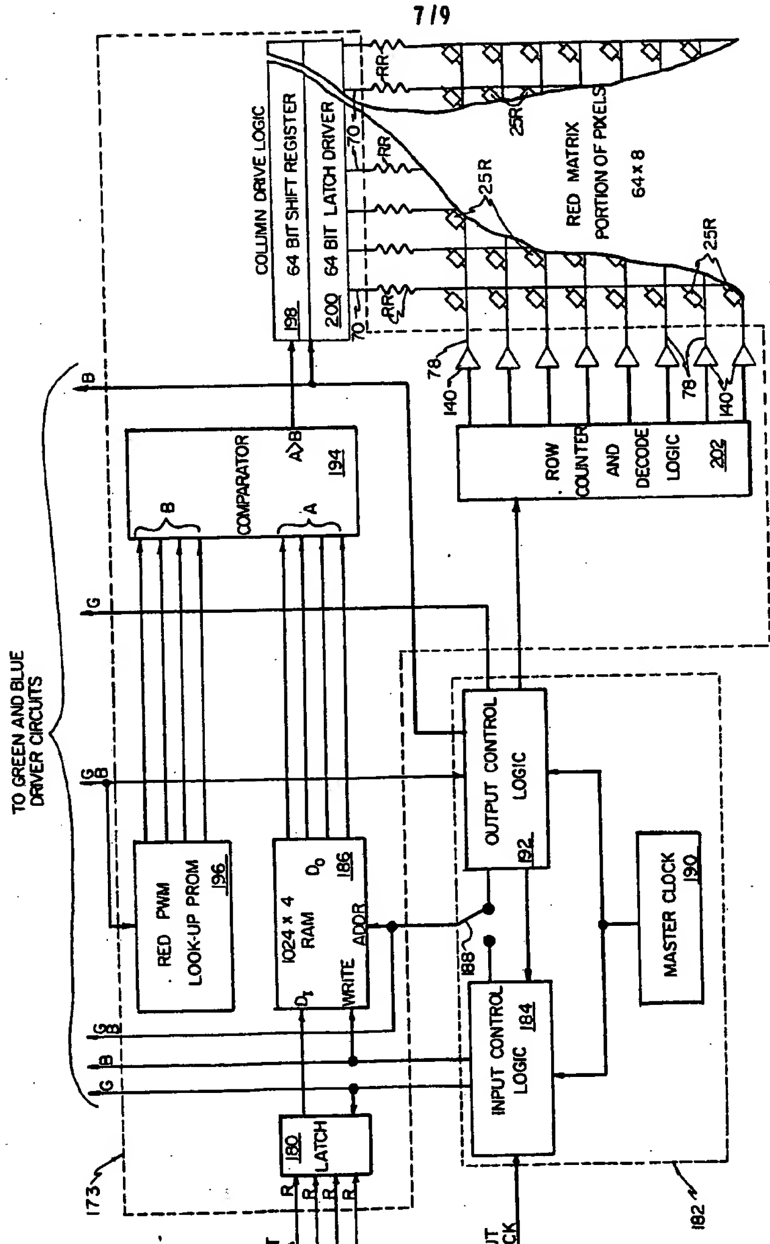


Fig. 11

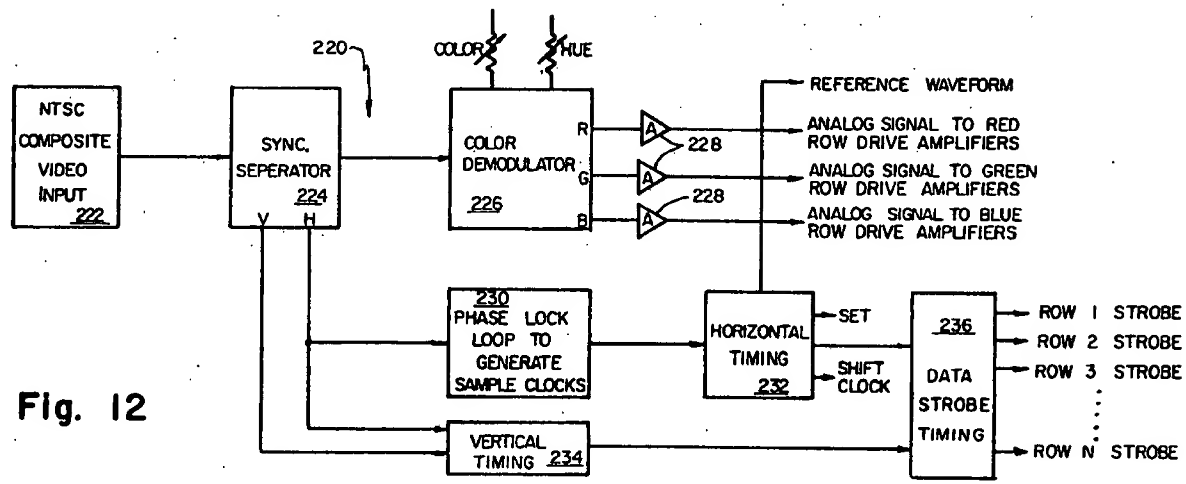

NTSC COMPOSITE VIDEO INPUT 222
220
SYNC. SEPERATOR 224
V
H
COLOR
HUE
COLOR DEMODULATOR 226
R
G
B
A
228
REFERENCE WAVEFORM
ANALOG SIGNAL TO RED ROW DRIVE AMPLIFIERS
ANALOG SIGNAL TO GREEN ROW DRIVE AMPLIFIERS
ANALOG SIGNAL TO BLUE ROW DRIVE AMPLIFIERS
230 PHASE LOCK LOOP TO GENERATE SAMPLE CLOCKS
HORIZONTAL TIMING 232
SET
SHIFT CLOCK
236 DATA STROBE TIMING
ROW 1 STROBE
ROW 2 STROBE
ROW 3 STROBE
ROW N STROBE
VERTICAL TIMING 234

Fig. 12

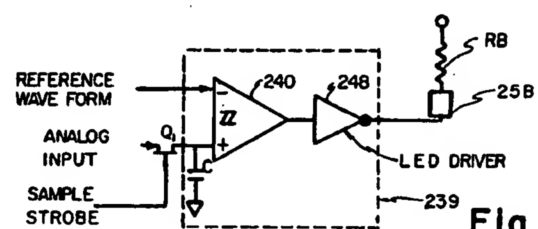
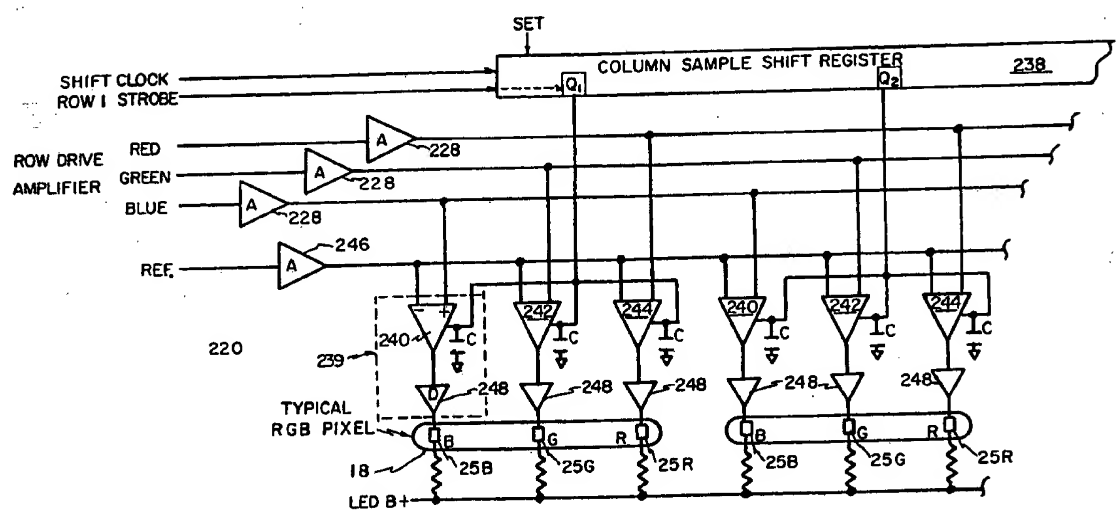

REFERENCE WAVE FORM
ANALOG INPUT
SAMPLE STROBE
240
248
RB
25B
LED DRIVER
239

Fig. 14



SET
COLUMN SAMPLE SHIFT REGISTER
238
SHIFT CLOCK
ROW 1 STROBE
Q_1
Q_2
ROW DRIVE
AMPLIFIER
RED
GREEN
BLUE
REF.
A
228
246
220
239
240
242
244
C
248
TYPICAL
RGB PIXEL
18
LED B+
B
G
R
25B
25G
25R

Fig. 13

SPECIFICATION

Solid state color display system and light emitting diode pixels therefor

This invention relates generally to display equipment and more particularly to a solid state color display system suitable for a color display and discrete elements therefor each comprising a compact array of light emitting diodes.

In the conventional construction of a large color display system (for example apparatus for displaying advertising, pictures, or the like at stadia, etc.), the words or pictures are formed by selectively turning on or off colored electrical lamps in predetermined patterns (this will produce what is known as cartoon color), or CRT types which are miniture TV screens which then provide the capability to produce true color (any color in the spectrum). Both systems present difficult problems.

The electric lamps have poor color rendition, which results from the fact that the electric lamps emit colors by having their filaments heated to red heat or a white orange color. Therefore, in order to produce colors, colored glass filters are used to selectively filter to the color desired. Since electric lamps on the order of 7 watts or more have been generally used, a large display (using thousands of lamps) consumes a large amount of electrical power and generates a large amount of heat.

A display using CRTs requires a large amount of power also and, although not much electrical power or heat is generated by the CRT, the circuitry required to drive and control the intensity is extensive and is very costly to manufacture and operate.

Both types of displays are subject to short lamp life, on the order of 8000-10,000 hours, which requires costly maintenance to replace them.

While light emitting diodes (LEDs) have been used in displays, they have been used in small installations or devices such as calculators and indicators. Their use in large displays has been rejected as impractical due to the small amount of luminance available for the standard LED. The luminance emitted by an LED chip over an area of approximately .014" by .014" (0.0002 square inch area) is diffused over an area of approximately 0.0628 square inches. Therefore, the light is diffused over an area 300 times larger than the source chip and hence the light emitted is unacceptably low.

In those situations, where a discrete LED is used in a matrix, (see Teshima, U.S. Patent No. 4,271,408) the display would have to use large collimating lenses that pick up the luminance from several discrete LEDs.

In array uses of LEDs, such as mentioned by Ichikawa (U.S. Patent No. 4,445,132), a flat panel display results. The method described by Ichikawa would be useful in small flat panel displays, the density and amount of circuitry required to drive each module would be both costly and prohibitive in a large matrix display used to display alphanumerics and animations.

The present invention largely overcomes or alleviates the aforementioned problems of the prior art and provides novel and unobvious solid state color display systems, including the large scoreboard type, and light emitting diode pixels forming the discrete light source elements thereof. A large number of LED chips typically comprise each pixel and the pixels are placed in a matrix and selectively illuminated under the control of driving circuitry. The light emitted is determined by the type of LEDs used in the array. Using three colors, blue, red, green that are controlled by separate driving circuitry, accommodates generation of any color in the spectrum.

According to the present invention there is provided a matrix display apparatus comprising a plurality of separately illuminable light emitting elements, each element comprising differently colored sets of light emitting diodes and each set containing light emitting diodes of a common color, and control means, including a pulse width modulator, for controlling the intensity of illumination of each set of diodes by means of pulse width modulation of an electrical source which, in use, is selectively connectable with the diodes, the modulation being related to signals received by the control means representative of the color to be displayed by each element at a given time.

With the array containing many LEDs spaced at close intervals, the whole array becomes a point source for the light; hence the effective light output is increased to the point that it becomes possible to have satisfactory contrast. The size of the array is determined by the number of LED chips included to achieve the size of pixel desired.

By using red, blue, green chip combinations on the same array with separate connecting leads, a true color system is created which will reproduce any color.

With the foregoing in mind, it is a primary object of the present invention to provide a novel solid state color display system and related method.

Another paramount object of this invention is the provision of a novel solid state discrete pixel, for a color display system, comprising an array of light emitting diodes (LEDs).

Specific embodiments of the present invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a cross section of an LED of an array or pixel in accordance with the present invention mounting to substrate;

Figure 2 is an enlarged front view of a tri-color [red, green, blue (RGB)] LED array or pixel in accordance with the present invention;

Figure 3 is a reduced scale cross section of the LED array or pixel taken along lines 3-3 of Figure 2;

Figure 4 is a front view of a typical series-parallel cathode/anode printed circuit board forming a part of the illustrated LED pixel;

Figure 5 is a series-parallel anode/cathode circuit diagram for LED pixels according to the present invention;

Figure 6 is an exploded cross section of a typical

electrical connection arrangement for an LED pixel in accordance with the present invention;

Figure 7 is a fragmentary front view of a matrix display using LED pixels according to the present invention;

Figure 8 is a schematic block diagram of an eight color RGB digital display system driven by a computer controlled message center;

Figure 9 is a schematic of a typical RGB driver circuit forming part of the system of Figure 8;

Figure 10 is a schematic block diagram of another RGB 4096 color digital display system optionally driven by either a computer controlled message center or a video digitizer;

Figure 11 is a schematic of a driver circuit forming a part of the display system of Figure 10;

Figure 12 is a schematic block diagram of a RGB analog display system which processes composite video to the LED pixel display of the present invention;

Figure 13 is a schematic of analog RGB driver circuitry used in conjunction with the display system of Figure 12; and

Figure 14 is an enlarged fragmentary circuit diagram of part of the circuit of Figure 13 by which selected LEDs of any pixel are turned on and off and the brightness thereof controlled.

In general, the Figures illustrate presently preferred color embodiments of solid state display systems and light emitting diode pixels therefor. Each pixel light source comprises a large number of LED chips arranged compactly to provide a discrete element light source of sufficient output to be viewed clearly from a substantial distance (on the order of 300-600 feet or greater). The arrays or pixels of LEDs are placed in a matrix suitable for use in large scoreboard displays, message centers and other large, intermediate and small display systems. Each pixel comprises a sufficient number of connecting leads to provide for each color of LEDs contained in the specific pixel array. Each pixel also accommodates the necessary electric connections to multiplex driving circuitry. The light emitted by each pixel is determined by the type or types of LEDs used in the array. Use of LEDs which produce the three primary colors, red, green and blue, controlled by drive circuitry, provides the capacity to create any one of a plurality of colors.

Discrete elements or pixels in accordance with the present invention provide a light source having satisfactory contrast. The size of each pixel is a function of the number of LED chips included for the type of display needed.

As mentioned heretofore, the actual dimensions of each discrete LED pixel or light source, generally designated 18 in Figure 1, may vary. Once the dimensions have been selected for a given display, an appropriately dimensioned substrate layer 20 is provided. In the illustrated embodiments, the substrate layer 20 can be comprised of glass epoxy printed circuit (PC) board or dielectric ceramic upon which conductive areas are created using thin or thick film technology currently available.

The utilization of such technology produces alternate cathode and anode conductive strips or fingers 22 and 24, respectively. See Figures 1 and 4. The manner in which the conductive layers or strips 22 and 24 are produced creates an integral bond at the two interfaces 26 (Figure 1) between the substrate 20 and each conductive strip 22 and 24. The cathode conductive layers 22 may be joined electrically and an exposed conductive cathode connection terminal provided. Likewise, the anode conductive layers 24 may be electrically joined and an exposed conductive anode connection terminal provided.

LED chips 40 are superimposed upon a layer of commercially available conductive epoxy 42 at predetermined spaced intervals along each cathode conductive layer 22. It is presently preferred that the LEDs be spaced at approximate horizontal and vertical intervals of about 0.050 to 0.10 of one inch to insure that the entire array appears to the eye of the viewer as a point source of light. After all LEDs are in place, the substrate is heated sufficient to melt the conductive epoxy under each led chip. After the conductive epoxy has cured, the chip is thereby bonded in place. A conductive wire 46 is connected from the anode of each LED chip 40 to the adjacent common anode conductor or strip 24. The process of bonding each connecting wire or conductor 46 to the anode of each LED chip 40 and to the adjacent anode conductor 24 is well known and need not be described in this specification.

It is presently preferred, as illustrated in Figure 2, that each discrete LED pixel or light source 18 comprise red, green and blue LEDs arranged in a pattern, such as alternative rows and driven so that the intensity or brightness of each color may be selectively varied between zero and maximum intensity whereby, when the three primary colors are integrated, any desired color may be displayed by the pixel 18.

It is also presently preferred, as illustrated in Figure 3, that provision be made at each pixel for avoiding loss of light intensity. More specifically, a reflector plate 48 may be contiguously superimposed, at the back surface 49 thereof, upon the front surface of the layer 22 comprising the cathode and anode conductors. Reflector plate 48 comprises a plurality of tapered apertures 50 arranged for each to receive, at the base thereof, one of the pixels in visually exposed relation. The apertures 50 are illustrated as being circular and as providing an outwardly divergent tapered reflective surface 52. A transparent lens 56 is continuously superimposed, at the flat back surface 54 thereof, upon the flat forward surface 53 of the reflector 48. The forward surface 58 of the lens 56 has a curved shape or is crowned. Individual collimating lenses may also be molded over individual LEDs.

Each pixel 18 comprises an anode pin 60 for each color and a cathode pin 62 for each color. See Figure 3. Each RGB pixel 18 thus has separate red, green and blue cathode pins 62R, 62G and 62B, and separate red, green and blue anode pins 60R, 60G and 60B. The red, green and blue cathode conductors 22 are respectively connected to the red, green and blue cathode pins 62. All red, green and blue anode conductors 24 are respectively

connected to the red, green and blue anode pins 60. A presently preferred arrangement of red, green and blue cathode and anode conductors 22R, 22G and 22B and 24R, 24G and 24B is illustrated in Figure 4. Red, green and blue LEDs are respectively designated 40R, 40G and 40B, in Figure 4.

The series-parallel printed circuit of Figure 4 is shown schematically in Figure 5. Application of a separate voltage pulse having a predetermined voltage to each of the respective groups of red, green and blue anode connectors of a pixel provides the capacity to produce any one of a plurality of colors ranging across the entire spectrum. Resistors RR, RG and RB are respectively used in series with the RGB anode terminals, respectively to cause all LEDs forming any one of the three RBG circuits to have a selected uniform brightness. The collective red, green and blue LED circuits of each pixel are designated 25R, 25G and 25B, respectively in Figure 5.

Reference is now made to Figure 6 which shows the preferred structure for connecting each discrete LED light source arrays 18 to driving circuitry. Specifically, each anode conductive pin 60 (one each for red, green and blue), mounted to substrate backing 20, is inserted into a matching conductive female receptacle 72 of a driving circuitry anode conductor 70. One such anode conductor 70 is provided for each of the three RGB pins 60.

The three anode pins 60 are respectively aligned with and are releasably press fit into female electrical receptacles 72 of the driving circuitry. The three female receptacles 72 for each pixel are firmly carried by a mounting display printed circuit board 74. Similarly, the three cathode pins 62 of each pixel 18 are respectively aligned with and are releasibly press fit into conductive electrical receptacles 76 of the driving circuitry. Each of the three receptacles 76 is electrically connected to its own separate cathode conductor 78.

When all of the pixels 18 of a given display system have been mounted to the board 74, as described, the display configuration of Figure 7 is created.

One typical multi-color matrix driving circuit 100 is shown in Figure 8. Circuitry 100 uses an available computer controlled message controller 102. The message controller 102 is conventionally programed to produce a series of red, green and blue digital signals so that a corresponding visual image is presented on the face of a scoreboard or like display 104. Display 104 is illustrated as comprising one hundred twenty eight (128) columns and forty (40) rows of pixels 18, subdivided into five (5) panels 106 each comprising one hundred twenty eight (128) columns and eight (rows) of pixels 18. Displays of other sizes can be used as desired.

The computer generated RGB digital data (in raster scan format), describing the "on", "off" and intensity of each LED of each tri-color pixel and representative of the image to be displayed, is transmitted in a known and suitably modulated serial data format from the computer controlled message controller 102 along RGB conductors 108, 110 and 112, respectively, to a serial receiver apparatus 114. Controller 102 can be any suitable commercially available computer controlled message controller. For example, a model 1000 EC controller with three display interfaces [part no. 11231 available from Integrated Systems Engineering, Inc. of Logan, Utah]. Three data bits are required to define the desired state of each pixel 18. One bit is, therefore, assigned to control each of the three colors of the pixel 18. In this manner, each pixel 18 can be directed to emit any one of eight colors. This type of color rendering is known as cartoon color.

The receiver 114 may be a single integrated device for the signals for all three colors or separate receivers, one for the signals for each of the three colors. Suitable serial receivers are also available from Integrated Systems Engineering, Inc. For example, part no. 10003 may be used for each of the three receivers. The receivers 114 de-multiplexes, respectively distributes or switches the RGB data and routes 8 rows of said data via three RGB independent cable conductors to an 8 row driver 116R, 116G, 116B. Five drivers of each type, i.e. five 116R, five 116G and five 116B are required, one of each for each 8 row display panel 106. Each driver 116R, 116G, 116B may comprise part no. 10000 available from Integrated Systems Engineering, Inc.

A power source 122 supplies electrical energy to the drivers 116R, 116G and 116B and to the pixels 18 of the display 104. If desired, more than one power source may be substituted for source 122. One suitable power source is part no. 10025 available from the Integrated Systems Engineering, Inc.

The details of one of the RGB driver circuits 116R, 116G, 116B for an 8 color digital LED display is illustrated in Figure 9. Specifically, the red driver circuit 116R is illustrated and described, it being understood that the 116G and 116B are structurally and functionally the same.

In the driver circuit 116R, red rows of digital data, issued from the receiver 114, are communicated serially to a conventional shift register 126, where the 8 serial bits of input data are converted to a parallel word, and from thence the parallel data are addressed and written to a RAM memory 128 using the eight input conductors, preferably during a frame update.

An output control logic signal, issued by the logic 132, is communicated to input control logic 130 which enables a write cycle to occur in a conventional fashion, with switch 131 connecting logic 130 and memory 128 for correct addressing of data.

The RAM memory 128 uses a time shared process for outputting the data to the multiplexed display in such a fashion that each discrete element image and the color thereof are periodically refreshed.

With the address switch 131, positioned as shown in Figure 9, and with output control logic 132 disabling input control logic 130 and shift register 126 so that temporarily no further red data are written into RAM memory 128. Red data are properly addressed and caused to be output, using

the eight output conductors 134, from RAM memory 128 to a 1 of 8 selector of demultiplexer 135, which selects one of eight rows of data and communicates the same along conductor 137 to red shift register 136 and from thence across latch circuit 138 along anode conductors 70R to the columns of red LED circuits 25R of the display. Buffers 140 supply current across cathode conductors 78R to the red LEDs on a row by row sequential basis. Selector 135 may be demultiplexer part no. HC151 and decoder part no. HC237, available from Motorola, Texas Instruments, among others.

While only red pixel diodes are illustrated in Figure 9 and while only the operation thereof has been described for one 8 row display panel, it is to be appreciated that the remainder of the red and all of the green and blue pixel diodes are identically connected and utilized.

Thus, the driver circuits 116R, 116G, 116B buffer the data and, using conventional LED multiplexing techniques, drives rows and columns of LED pixels. In this way, three independent sets of outputs are utilized to drive the rows and columns.

Another typical multi-color matrix driving circuit 150 is shown in Figure 10. Circuitry 150 comprises an available computer controlled message controller 152, which is comparable to controller 102, but conventionally programmed to produce four digitized bits of red, green and blue data, respectively (12 bits/pixel). In this way, any one of 4096 colors may be selected and displayed at any pixel 18 of an LED pixel display 154. Display 154 is illustrated as comprising sixty-four (64) columns and forty (40) rows of pixels 18, made up of five (5) panels 156 each comprising sixty-four (64) columns and eight (8) rows of pixels 18. Displays of other sizes may be used.

Circuitry 150 comprises an additional or alternative source of data, i.e. a video digitizer 158, which receives video signals across switch 160 from any suitable source of video signals such as a video camera 162, a VCR 164 or broadcasted video (tv) signals via antenna 166 and tuner 168.

A switch 170 allows the user to select between controller 152 and digitizer 158 as a source of video input. In either case, data digitized into 12 bits/pixel are transmitted, across twelve (12) conductors (4 each for RGB data, respectively), to a serial receiver 172. This data is in row-by-row raster scan format, and describes the on, off and intensity level for each color of each LED of each tri-color pixel. The data, collectively represents the image to be illuminated at the display 154.

The receiver 172 de-multiplexes and distributes or switches the 12 bits of RGB data and routes 8 rows of data via independent conductors to the drive electronics of RGB drivers 173, 174 and 175. Each driver 173, 174 and 175 contains red, green and blue electronics, respectively.

A power source 176 supplies electrical energy to the drivers 173, 174 and 175 and to the pixels 18 of the display 154.

In each RGB driver circuit 173, 174 and 175, RGB rows of digital data (four bits/color), issued from the receiver 172, are respectively communicated to red, green and blue latch circuit. One such latch circuit 180 for red driver 173 is shown in Figure 11. The latch 180 captures and retains data until the input logic is allowed to process it into the memory, i.e. the latch 180 is a temporary buffer.

Apart from the control logic 182 of Figure 11, which is common to the driver circuits 173, 174 and 175 for each 8 row panel 156 of the display 154, each color has its separate, although identical 8 rwo driver electronics. Accordingly, only one driver circuit needs to be described, i.e. circuit 173, illustrated in Figure 11.

An input clock pulse, issued by the receiver 172, is communicated to input control logic 184 to control or enable the transfer of data into the red RAM memory 186 in a conventional fashion, with Switch 188 connecting logic 184 and red memory 186 for correct addressing of data under the timing control of master clock 190. Input control logic 184 causes newly received data to be written into RAM memory. RAM memory 186 holds the digital image of the current display. Master clock 190 establishes system timing requirements.

The RAM memory 186 uses a time shared process for outputting the data, under the timing control of master clock 190 and output control logic 192, to the red pixel LED multiplexed display in such a fashion that each image and the color thereof are periodically refreshed. Output control logic causes the current contents of the RAM to be read out for display processing.

With the switch positioned as shown in Figure 11 and with output control logic 192 disabling input control logic 184 so that temporarily no further data is written into RAM memory 186, red data, for example, are caused to be output from RAM memory 186 along four conductors to one side of a comparator 194. Four conductors also connect the other side of comparator 194 to a PWM Prom 196. Comparator 194 compares the output of the RAM to the output of the PWM Prom looking for conditions when data in the RAM should cause the associated LEDs to be turned on. PWM 196 is a programmable Read Only Memory, which contains the look-up table which causes the RAM data to conform to a pulse width modulated brightness scheme containing 16 different intensities.

The PWM Prom 196 is a decoding pulse width modulation permanently programmed Read Only Memory which uses a window technique to control when and for how long pixel color data is output from RAM 186 through comparator 194 to shift register 198, i.e. so long A Input is greater than B input. The Prom look-up table is customized to match the light output characteristics of the three different color LED dice.

As an example, a single row of data may be processed from RAM 186 to column drive shift register 198 sixty four (64) times in 1.0 millisecond. Thus, all 8 rows are processed in 8 milliseconds. Continuous scanning of all 8 rows every 8 milliseconds yields a refresh rate of 125 frames per second (fps). This is sufficient to reduce flicker and make the image appear solid to an observer.

Under control of logic 192, column data stored in

register 198 is communicated across latch driver 200 along anode terminals 70 to the columns of red LED circuits 25R of one panel of the display. Buffers 140 supply current to the cathode terminals 78 of the red LEDS of one panel, on row-by-row sequential basis, under control of logic 192 and row counter and decode logic 202.

While only red pixel diodes for 8 rows of the display are illustrated in Figure 11 and while only the operation thereof has been described, it is to be appreciated that the remainder of the red as well as all of the green and blue pixel diodes are identically connected and utilized.

Restated, the system of Figures 10 and 11 utilizes the digital approach of the light color method, and a digital form of pulse width modulation to drive each color within a pixel at any desired one of sixteen different intensities. Thus, 4 bits are used to define each LED's brightness level, and 12 bits define the entire pixel. This yields 4096 different color combinations. This large number of color combinations is sufficient to reproduce a video image so that an observer will experience realistic color reproduction.

The system of Figures 10 and 11 is operated in a manner similar to the eight color of Figures 8 and 9. In addition to the computer, a video source is added as an input alternative.

The receiver functions essentially the same as in the eight color system of Figures 8 and 9.

The driver also functions similar to the eight color system; however, the separation of the color signals into independent buffers produces the desired brightness based of 4 bit data analysis.

To keep flicker to a minimum and accomplish pulse width modulation within the time periods of the normal refresh cycle, the data rates from the buffer to the output shift registers must be greatly increased over the eigth color method. The encoded data from the Ram 186 is compared to the output of a PWM Prom. The ouptut of this Prom determines the length of 15 "on" states or conditions for each of the 16 possible brightness levels. (State zero, the 16th state, is an "off" state). Comparing the pixel color data to the PWM prom output will let either a 1 or 0 shift out to turn "on" or "off" a color within a pixel. The longer the value of the pixel data exceeds the value produced by the PWM Prom, the higher will be the apparent brightness of the LED.

Another multi-color matrix driving circuit 220, suitable for converting an NTSC, PAL or SECAM composite video into a continuously variable RGB display using analog data and tri-color LED pixels, is shown in Figure 12-14. Circuitry 220 comprises a source of NTSC, PAL or SECAM composite video 222. See Figure 12.

Using known techniques, a synchronized separator 224 and a color demodulator 226, with output amplifiers 228, are used whereby the NTSC signal is broken into its five primary components, i.e. horizontal synch (H), vertical sync (V), a continuously varying signal proportional to the amount of red in the picture (R), a continuously varying signal proportional to the amount of green in the picture (G), and a continuously varying signal proportional to the amount of blue in the picture (B).

The H signal is applied to a PLL (phase lock loop) 230 which produces a high frequency clock pulse. This clock pulse determines, in conjunction with horizontal timing circuit 232, the start of each video line, and establishes how often the video is sampled.

The V signal is used, in conjunction with the vertical timing circuit 234, to determine the start of frame timing. V and H, in conjunction with data stobe timing circuit 236, select which rows of video will go to the LED pixel display.

The final outputs, as a result of the described processing of the H and V signals will: (1) set a start bit sequentially into each row of column sample shift register 238 (Figure 13); (2) shift the bit from left to right within shift register 236 as each successive pixel is sampled; (3) output a strobe pulse to each row of pixels as such is updated; and (4) produce a reference waveform of sufficiently high frequency to reduce the flicker that would otherwise result if the LEDs were pulsed at normal video rates.

Each pixel color requires a separate pulse width modulation decoder to establish the desired elements brightness. This is accomplished with a sample and hold circuit voltage comparator circuit, shown in Figures 13 and 14 and hereinafter described.

With reference to Figure 13, the set, shift clock and row strobe signals, eminating as described above, are delivered to a column sample shift register 238, while the RGB sequential pixel signals are respectively communicated to the positive terminal of separate RGB comparators 240, 242 and 244. The reference waveform, amplified at 246, is communicated to the negative terminal of each comparator 240, 242 and 244.

The video is sampled in succession by the action of the shift register 238 and the row strobe pulse. The value of the video is stored in the sample and hold comparator circuit 239. Using one field of a video frame, this value is updated 30 times per second.

With specific reference to Figure 14, which is an enlargement of one comparator circuit 239, the video signal is sampled when transistor Q is strobed "on", and stored in capacitor C. A reference waveform voltage is compared to the voltage stored in capacitor C. So long as the voltage in capacitor C is greater than the value of the reference, the output, across driver 248, will turn the associated LED's on. When the reference is greater than the voltage stored in capacitor C, the LEDs are "off". Thus, the longer any LED is "on" within the period, the greater the brightness and vice versa.

An update rate of 30 Hz is too slow to prevent flicker, so the reference waveform with a repetition rate in excess of 120 Hz is compared to the stored video. This comparison will yield a pulse, the width of which will be in proportion to the stored analog voltage. Thus each LED is pulse width modulated to yield the desired brightness.

CLAIMS

1. A matrix display comprising:

a plurality of multi-color solid state LED pixels arranged in a pattern;

each multi-color pixel comprising a plurality of differently colored sets of LEDs;

each set of differently colored LEDs of each pixel being electrically interconnected by separate conductor means;

a source of separate but coordinated series of signals representative of the desired color intensity to be obtained at each point in time from each set of differently colored LEDs of each pixel of the display, said source comprising pulse width signal modulating means which control the color intensity;

means simultaneously communicating said series of signals separately to each set of differently colored LEDs of each pixel whereby (a) the color of each pixel displayed to an observer at each point in time is a composite integration of the separate intensity level signals simultaneously delivered to the different colored sets of LEDs of the pixel, (b) the composite color displayed to an observer of all pixels of the display will at each point in time comprise an integrated image comprising many colors across the spectrum; and (c) the image and many colors thereof will change from time to time as the intensity level signals of the series change.

2. The display according to Claim 1 wherein the simultaneously communicating means comprise driver circuit means which systematically and sequentially drive the differently colored LEDs of each pixel of the display via the series of signals.

3. The display according to Claim 2 wherein the driver circuit means comprise memory means for temporarily storing said signals and means selectively outputting the stored signals to the LEDs in a scan format.

4. The display according to Claim 2 wherein the driver circuit means comprise means for refreshing the color of the LEDs of each pixel during the time interval of each image by recommunicating the current series of data from storage to the LEDs.

5. The display according to Claim 2 wherein the drive circuit means comprise control logic means which cause the demultiplexed signals to be output to scan means from which each series of signals is repeatedly communicated on a sequential basis to the LED pixels.

6. The display according to Claim 1 wherein said source comprises video digitizer means.

7. The display according to Claim 1 wherein said source comprises computer means.

8. The display according to Claim 1 wherein said source comprises means issuing NTSC, PAL, or SECAM television signals.

9. The display according to Claim 1 wherein sample and hold means are interposed between standardized value means and each output signal to retain the intensity of each color of each LED for each pixel for extended periods of time.

10. The display according to Claim 1 wherein the pulse width signal modulating means comprise means by which image flicker is minimized.

11. A matrix display comprising:

a plurality of tri-color solid state LED pixels arranged in a pattern;

each tri-color pixel comprising three differently colored sets of LEDs;

each set of tri-colored LEDs of each pixel being electrically interconnected by separate conductor means;

a source of three separate but coordinated series of signals representative of the desired color intensity to be obtained at each point in time from each set of differently colored LEDs of each pixel of the display, said source comprising a data source and further comprising means by which the data are delivered to the sets of differently colored LEDs in a refreshing modulated scan data format, the rate of which substantially exceeds the rate at which data is issued for the data source;

means simultaneously communicating said three separate series of signals independently to each set of differently colored LEDs of each pixel whereby (a) the color of each pixel displayed to an observer at each point in time is a blended integration of the intensity level signals simultaneously but independently delivered to each of the three sets of LEDs of the pixel, (b) the composite color displayed to an observer of all pixels of the display collectively will at each point in time comprise one of a range of colors from across the color spectrum, and (c) the image and colors thereof of the display will change from time to time as the signals representing the intensity level of each set of LEDs of each pixel changes.

12. A method of displaying images of varying colors within the spectrum of a matrix display comprising:

providing an array of a large number of juxtaposed multi-color solid state integrated pixels arranged in a close matrix pattern, each pixel comprising sets of differently colored compactly arranged LEDs so that each pixel is an apparent composite point color light source to an observer of the array;

separately controlling and selectively electrically communicating from a source of video signals or computer signals several separate coordinated series of signals respectively to the sets of LEDs of each color;

in such a manner that each pixel will, at any point in time, display only one composite color comprising a visual integration of the plurality of coordinated signals delivered to the differently colored LEDs of each pixel and said one composite color each pixel will change from time to time as said plurality of coordinated signals changes whereby successive images each comprising varying array of composite colors across the spectrum, are sequentially visually illuminated on the matrix display.

13. Matrix display apparatus comprising a plurality of separately illuminable light emitting elements, each element comprising differently coloured sets of light emitting diodes and each set containing light emitting diodes of a common

color, and control means, including a pulse width modulator, for controlling the intensity of illumination of each set of diodes by means of pulse width modulation of an electrical source which, in use, is selectively connectable with the diodes, the modulation being related to signals received by the control means representative of the color to be displayed by each element at a given time.

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